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(54) VERTICAL PROBE ARRAY ARRANGED TO PROVIDE SPACE TRANSFORMATION

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(51) **Int. Cl.**
G01R 31/02 (2006.01)
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(52) **U.S. Cl.** **324/762.01**; 324/755.01; 324/755.04; 324/755.11

(58) **Field of Classification Search** 324/754, 324/761, 762; 439/862
See application file for complete search history.

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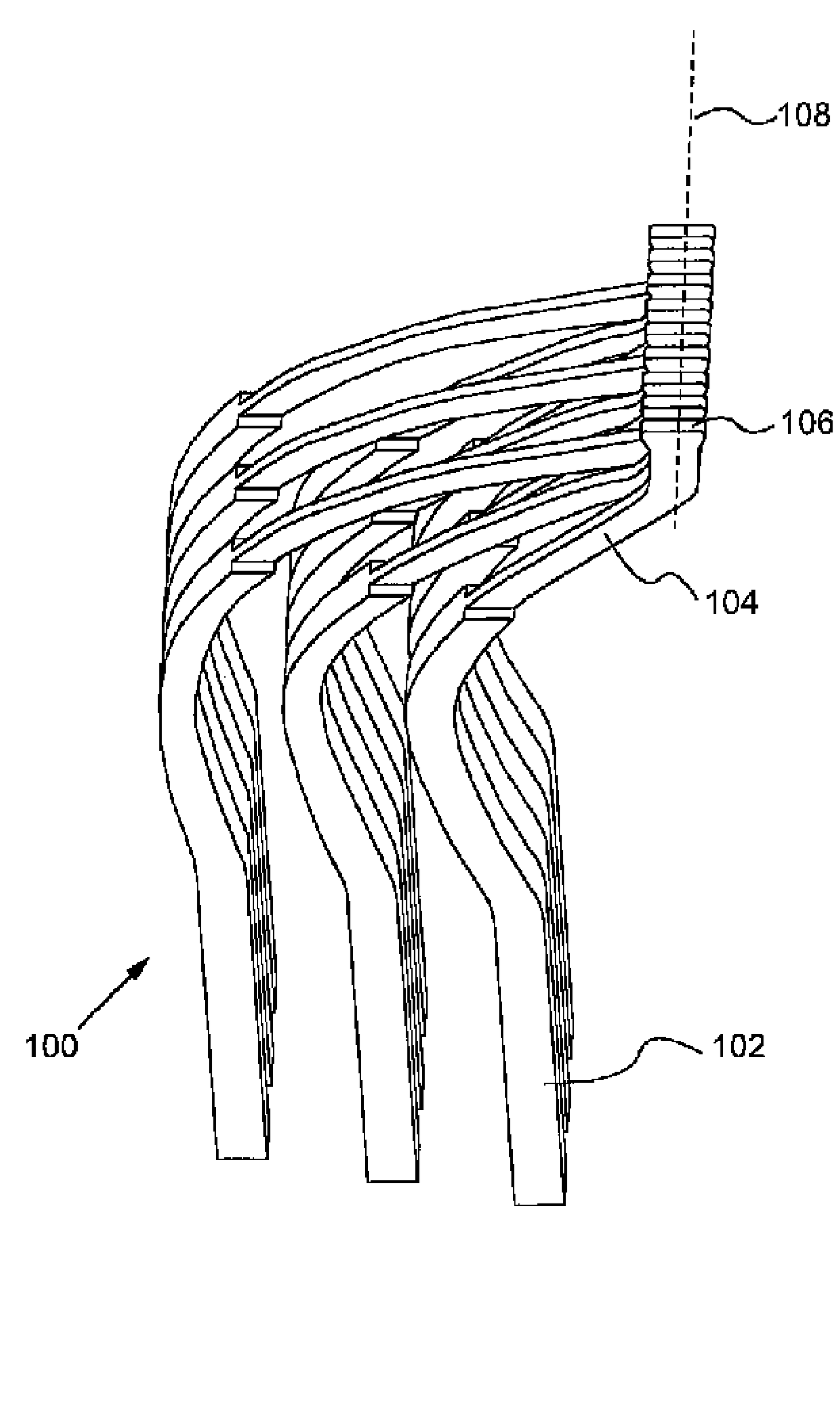
(57) **ABSTRACT**

Improved probing of closely spaced contact pads is provided by an array of vertical probes having all of the probe tips aligned along a single contact line, while the probe bases are arranged in an array having two or more rows parallel to the contact line. With this arrangement of probes, the probe base thickness can be made greater than the contact pad spacing along the contact line, thereby advantageously increasing the lateral stiffness of the probes. The probe tip thickness is less than the contact pad spacing, so probes suitable for practicing the invention have a wide base section and a narrow tip section.

29 Claims, 4 Drawing Sheets



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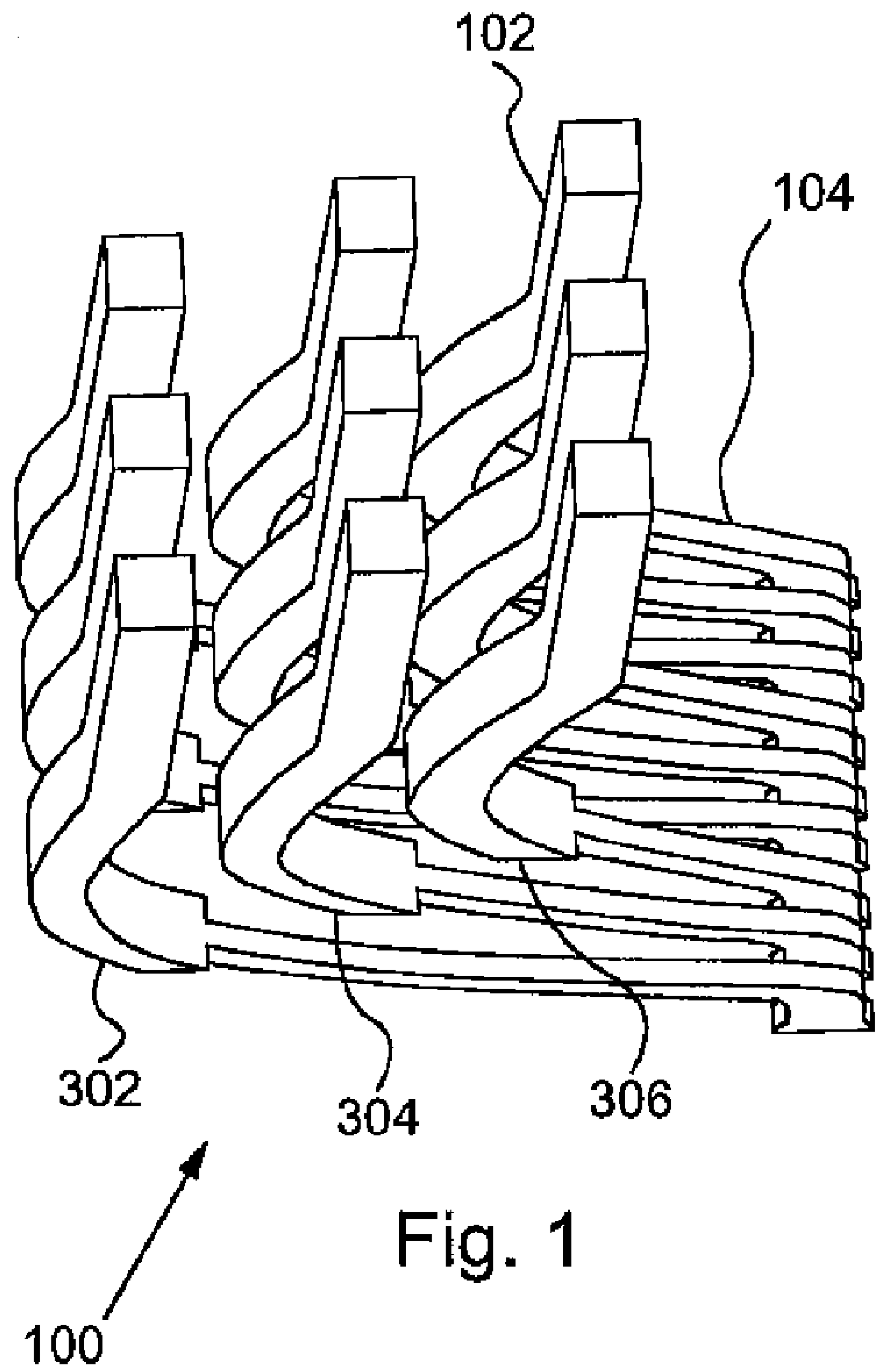

Fig. 1

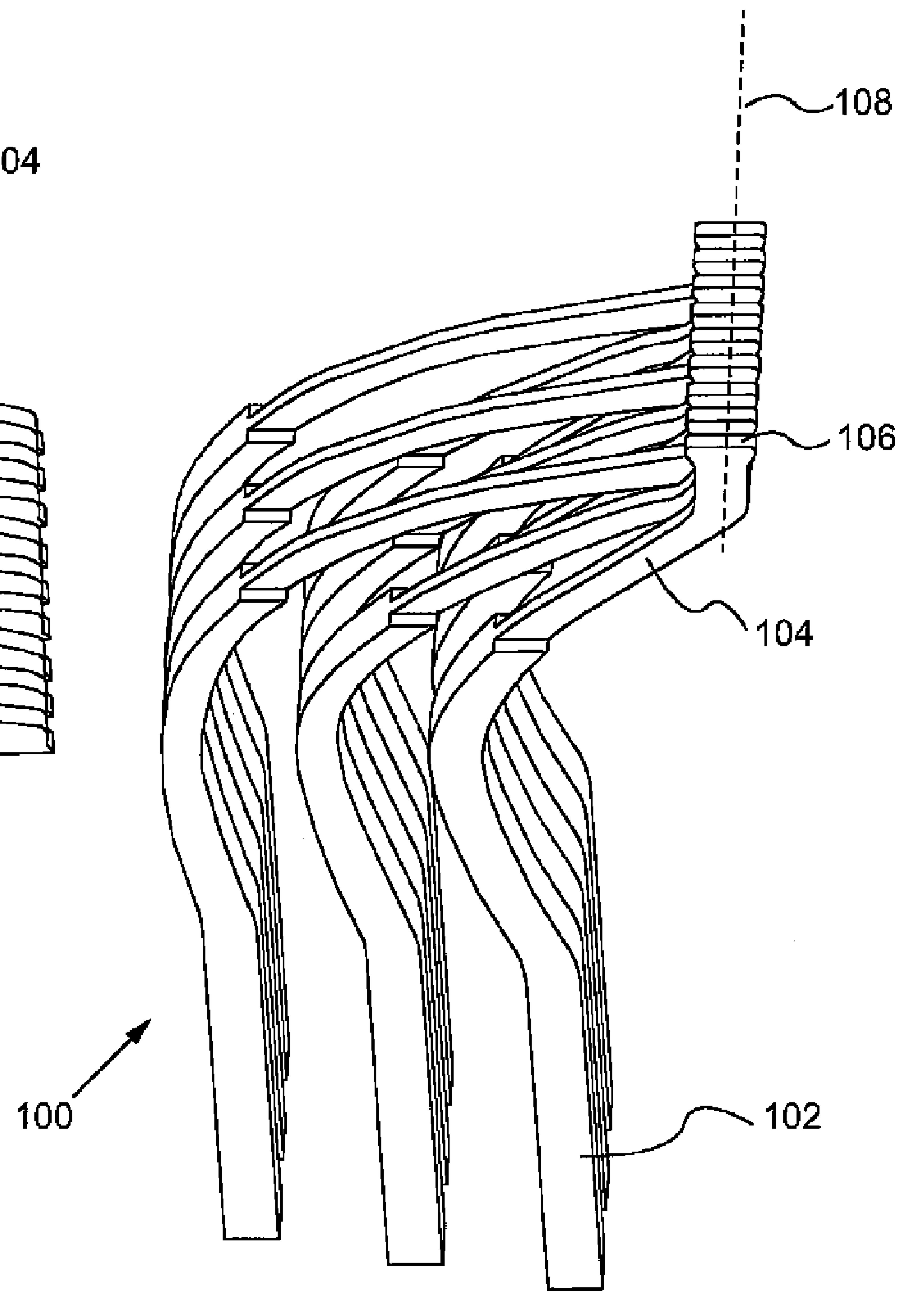

Fig. 2

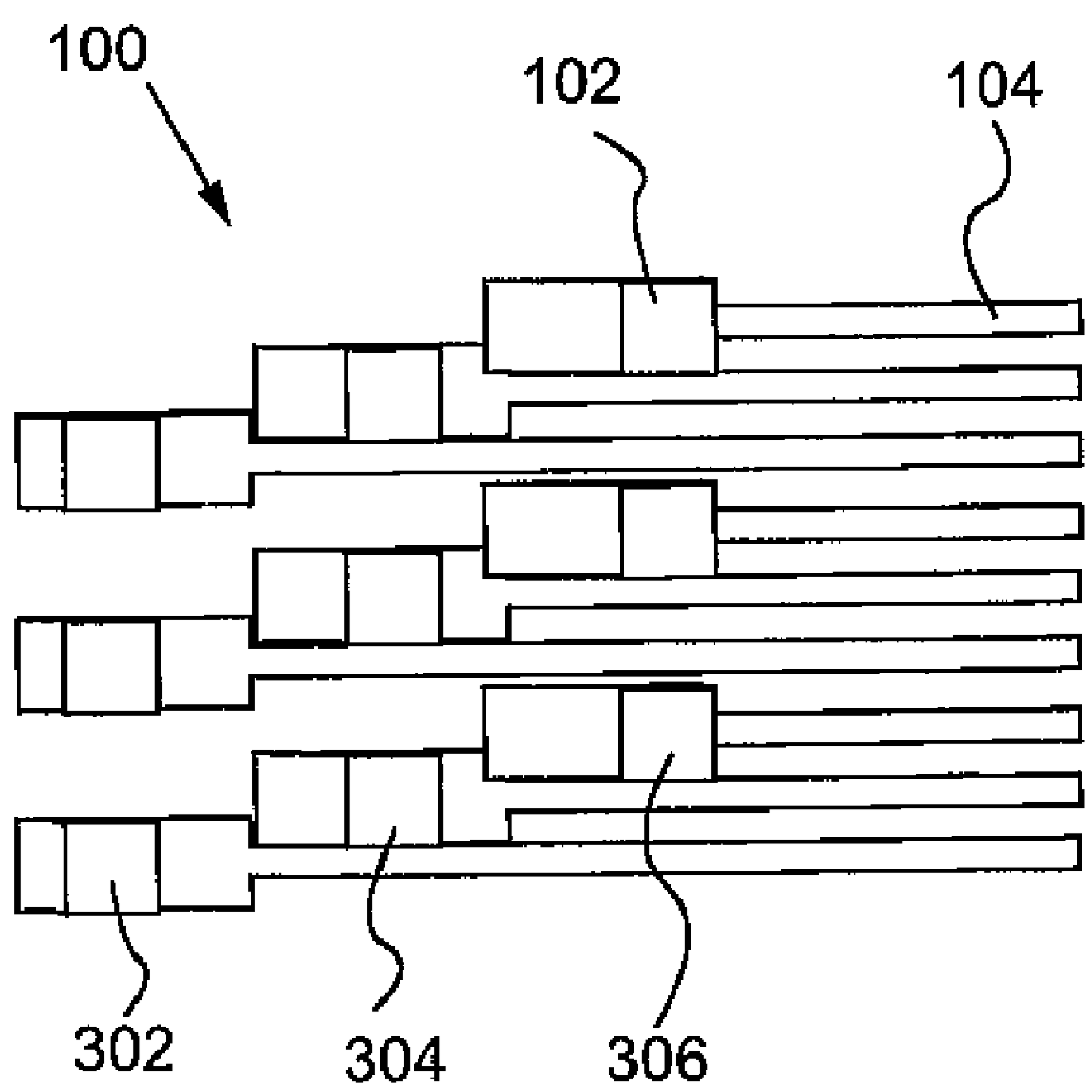

Fig. 3

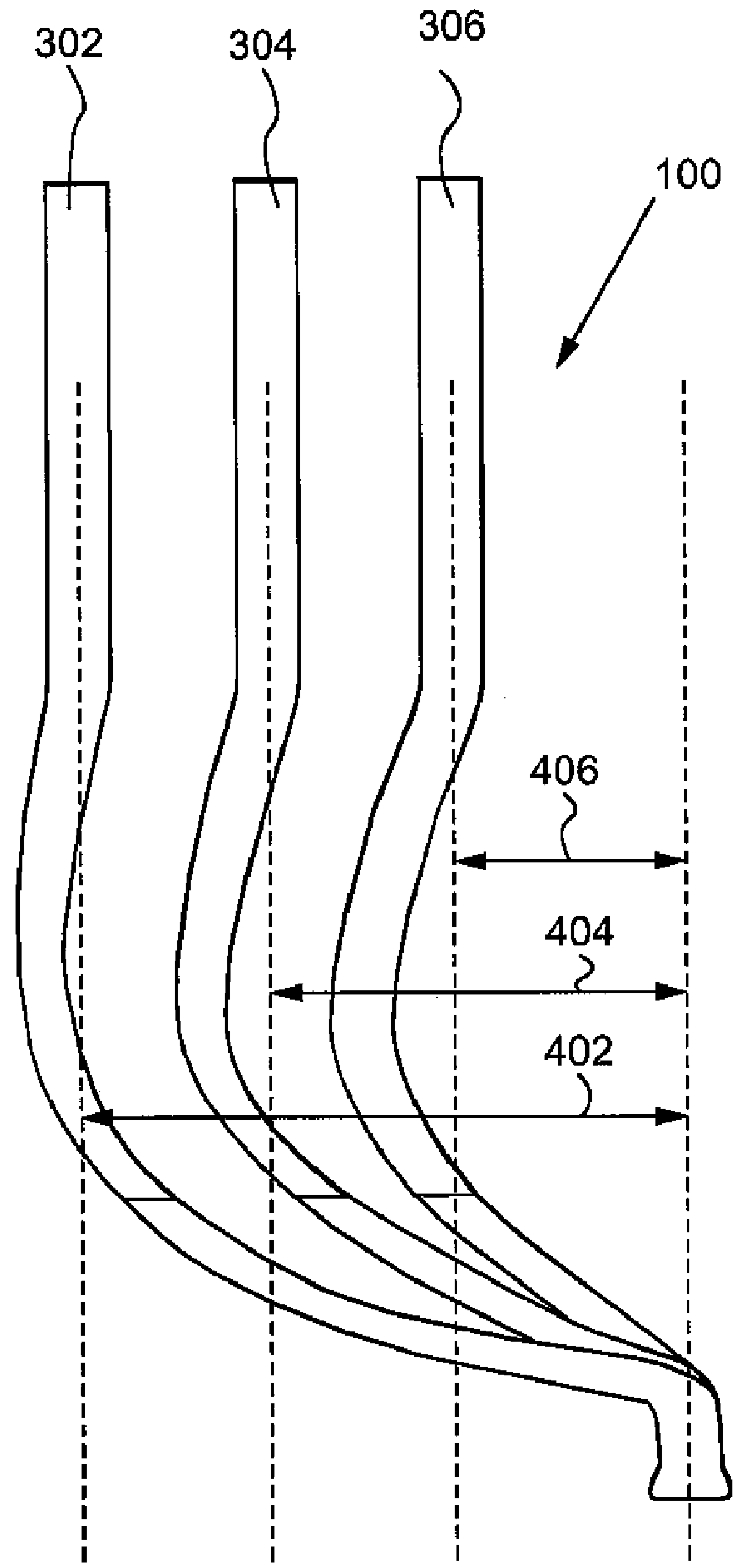

Fig. 4

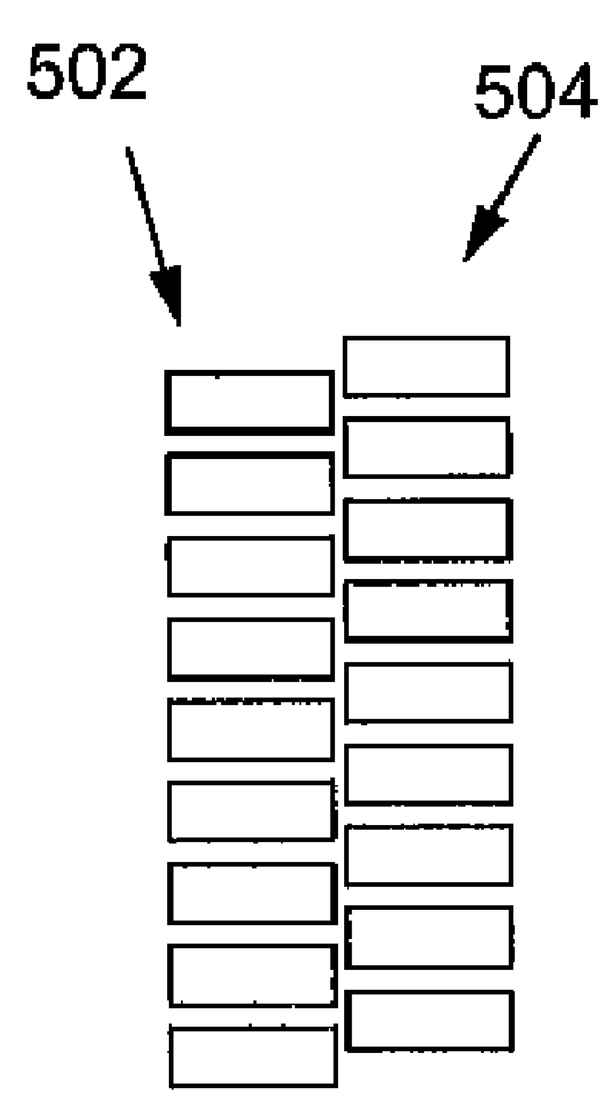

Fig. 5

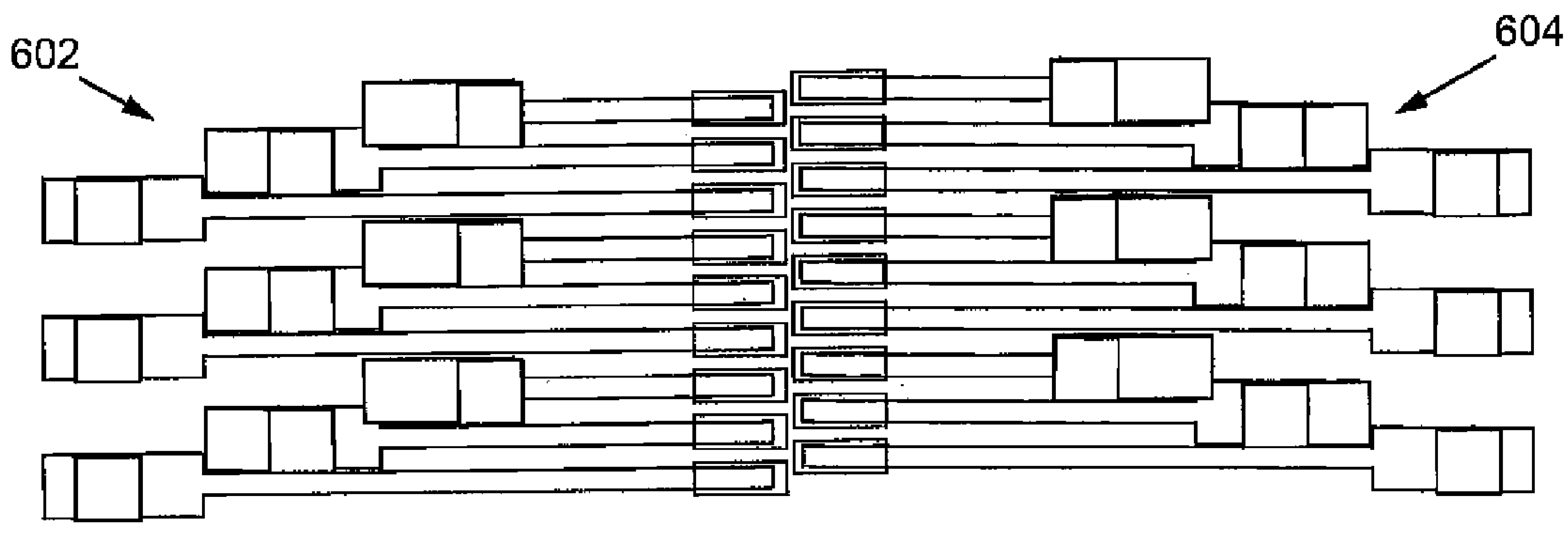

Fig. 6

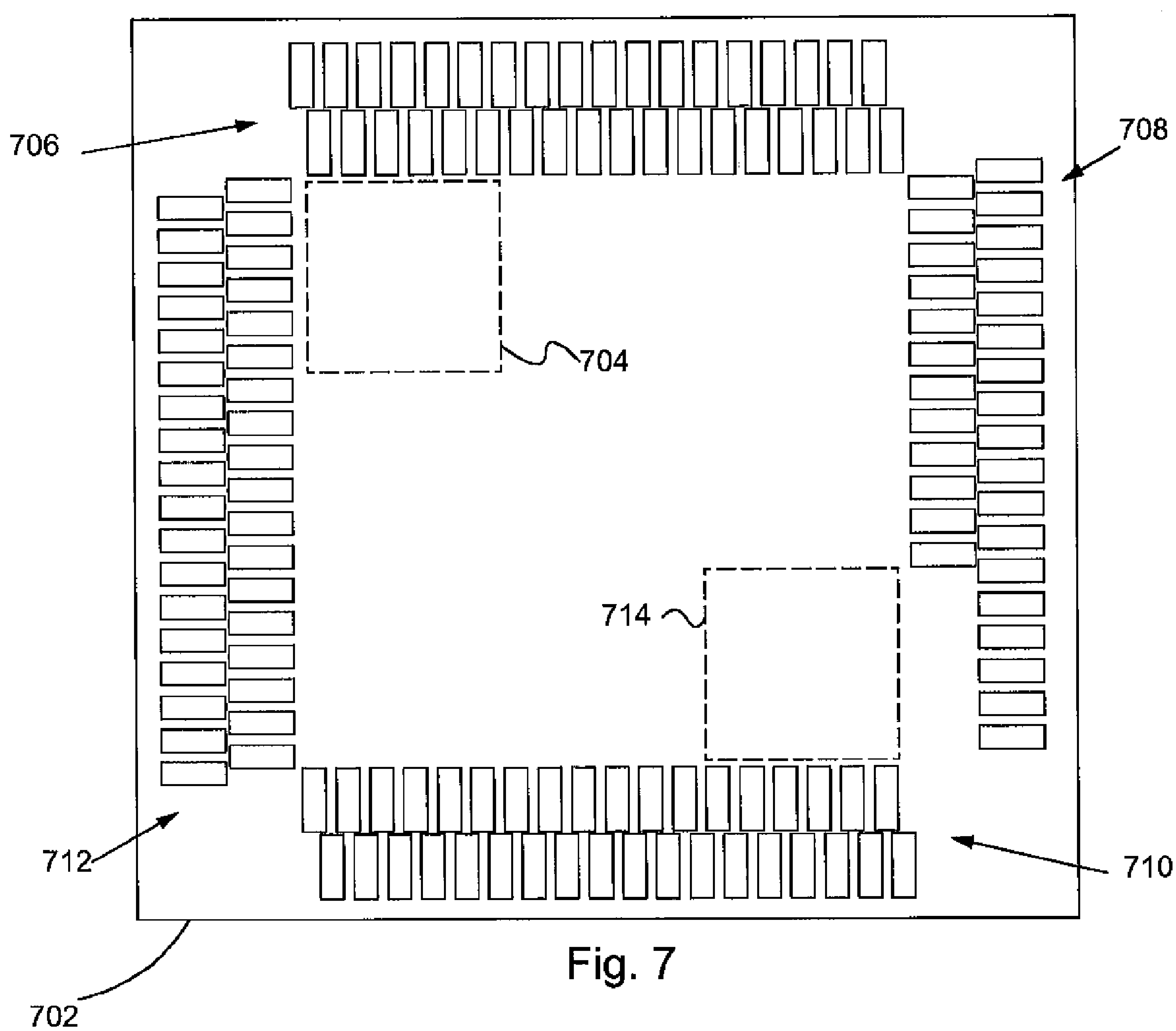

Fig. 7

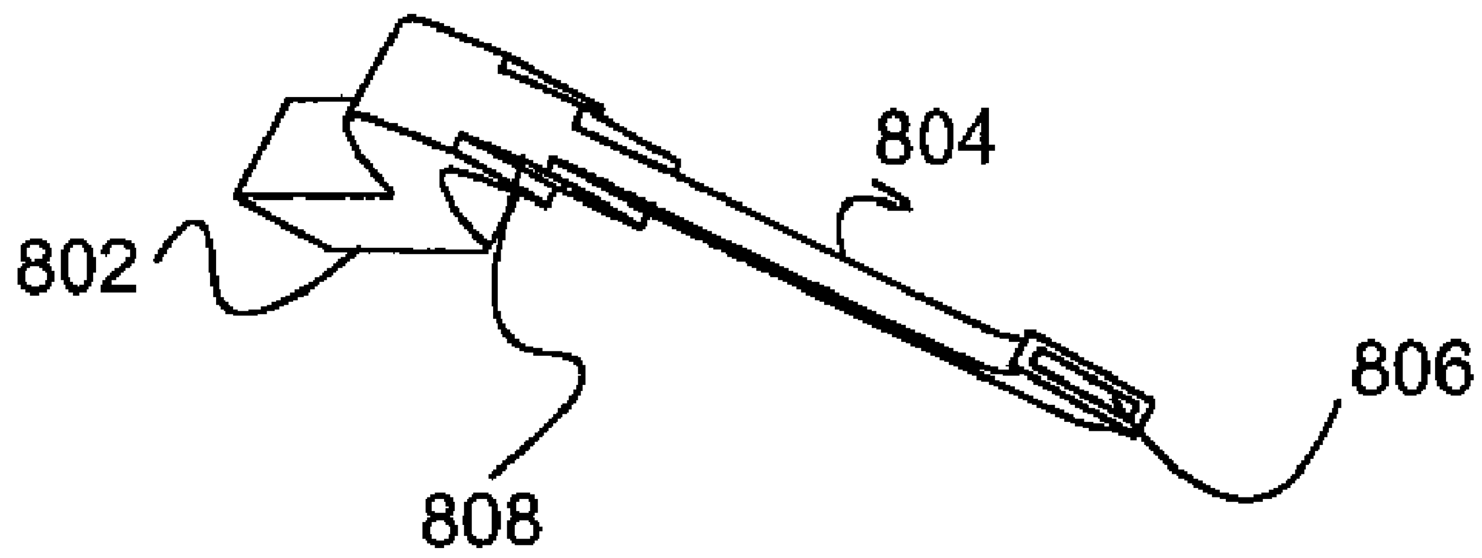

Fig. 8

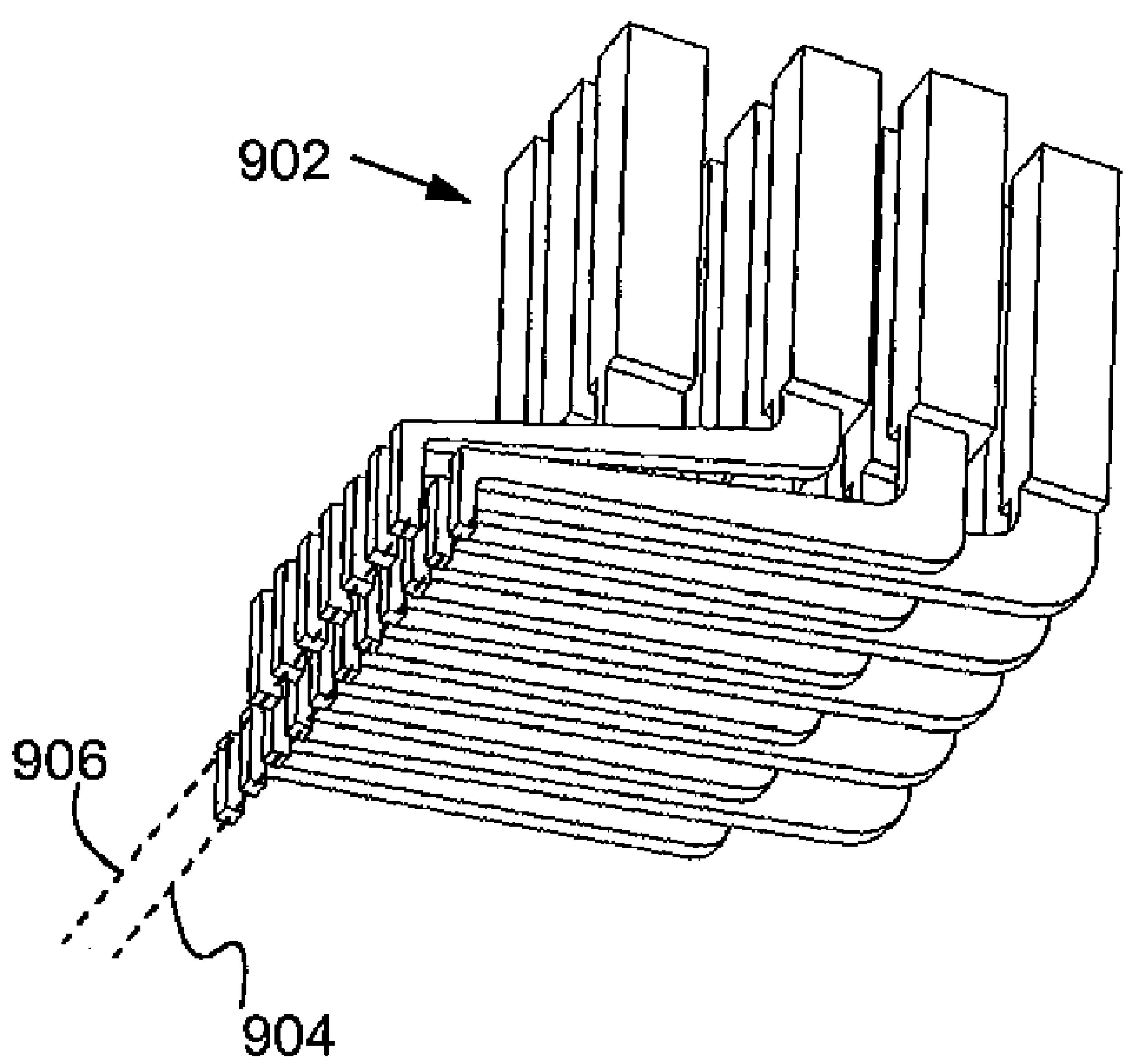

Fig. 9

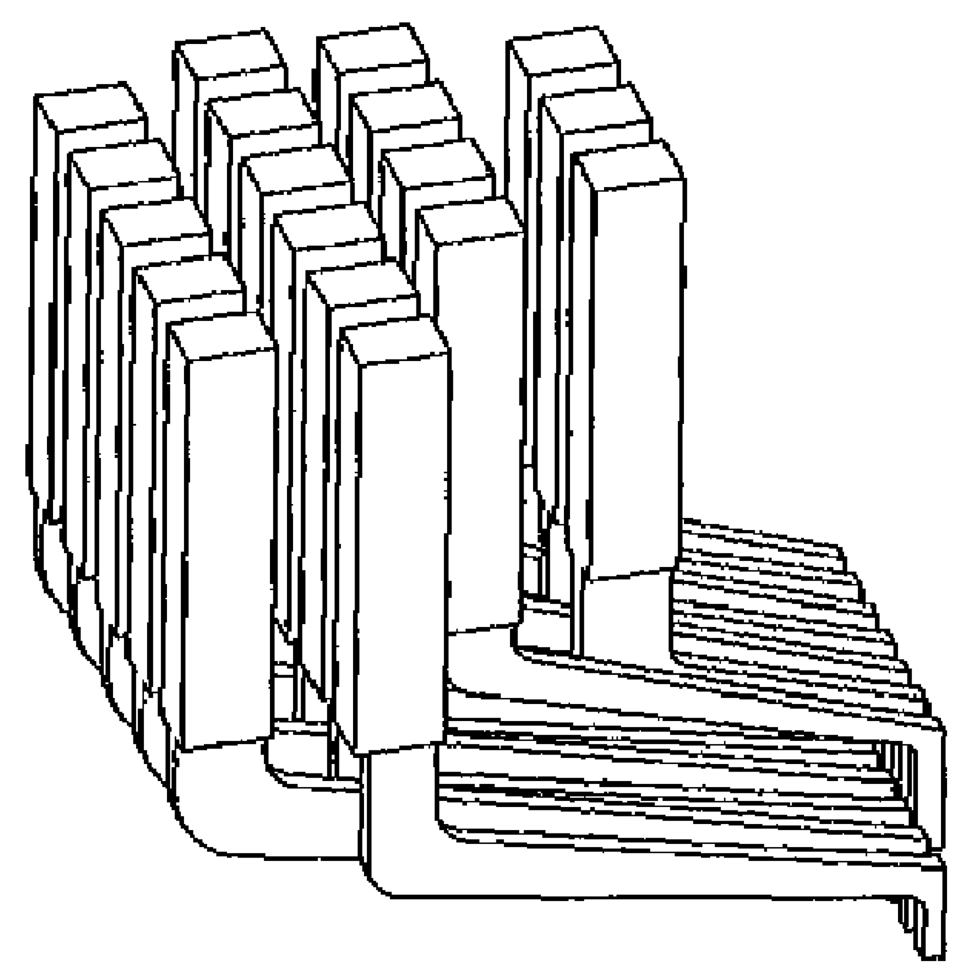

Fig. 10

VERTICAL PROBE ARRAY ARRANGED TO PROVIDE SPACE TRANSFORMATION

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 11/786,107 entitled "Vertical Probe Array Arranged to Provide Space Transformation", to January Kister, filed on Apr. 10, 2007, and the specification and claims thereof are incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to probe arrays for testing integrated electrical circuits.

BACKGROUND

Integrated electrical circuits are typically tested prior to final dicing and packaging. Such testing usually entails making temporary electrical contact to contact pads on the circuit or chip being tested. Probes or probe arrays are commonly employed to make such temporary electrical contact. Probes or probe arrays for this application have been under development for many years, since the ongoing technological evolution of chips and integrated circuitry to ever-smaller dimensions tends to raise problems which require new probing solutions.

For example, vertical probes have evolved significantly over time. In a vertical probe, at least a substantial portion of the probe is aligned along the vertical direction, where "vertical" is conventionally taken to the direction of probe travel when making contact. Vertical probes can provide improved control of scrub motion of the probe tip relative to the contact pad as contact is made, e.g., as described in U.S. Pat. No. 7,148,709 by the present inventor. Such improved control of scrub motion is increasingly important as contact pad dimensions decrease. Various aspects of arrays of vertical probes are also considered in U.S. Pat. No. 7,148,709, as well as in U.S. Pat. No. 6,443,784, U.S. Pat. No. 6,731,123, and U.S. Pat. No. 6,847,221.

Vertical probes often have a well-defined probe plane, such that deformation of the probe during contact occurs primarily in the probe plane without significant lateral (i.e. out of plane) motion. This situation is preferred in practice, because it allows an array of vertical probes to be closely spaced in a direction perpendicular to the probe plane, thereby facilitating making contact to a corresponding array of closely spaced contact pads. As long as the probe deformation is in-plane, undesirable contact between adjacent probes as a result of probe deformation during contact will not occur.

However, this approach can encounter difficulty as the contact pad spacing decreases, since decreased probe width (to accommodate the reduced contact pad spacing) can lead to an undesirable tendency of the probes to laterally deform. Such lateral probe deformation is highly undesirable, since it can lead to electrical contact between different probes of the same probe array.

Accordingly, it would be an advance in the art to provide probing of closely spaced contact pads with a vertical probe array having a reduced tendency for probes to laterally deform.

SUMMARY

Improved probing of closely spaced contact pads is provided by an array of vertical probes having all of the probe tips aligned along a single contact line, while the probe bases are arranged in an array having two or more rows parallel to the contact line. With this arrangement of probes, the probe base thickness can be made greater than the contact pad spacing along the contact line, thereby advantageously increasing the lateral stiffness of the probes. The probe tip thickness is less than the contact pad spacing, so probes suitable for practicing the invention have a wide base section and a narrow tip section.

The invention is also suitable for probing two parallel rows of closely spaced contact pads. In such applications, the rows of contact pad may or may not be offset from each other. The invention is suitable for use with any kind or shape of vertical probe, provided the lateral probe thickness varies as described above. For example, knee probes can be employed where the probe tip is aligned with the probe base axis (i.e., the knee "goes out" as much as it "comes back in"), or where the probe tip is between the probe base axis and the knee (i.e., the knee goes out more than it comes back in), or where the probe base axis is between the probe tip and the knee (i.e., the knee goes out less than it comes back in).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an oblique top view of a probe array according to an embodiment of the invention.

FIG. **2** shows an oblique bottom view of the probe array of FIG. **1**.

FIG. **3** shows a top view of the probe array of FIG. **1**.

FIG. **4** shows a side view of the probe array of FIG. **1**.

FIG. **5** shows two rows of contact pads having an offset with respect to each other.

FIG. **6** shows an embodiment of the invention where contact is made to two staggered rows of contact pads as in FIG. **5**.

FIG. **7** shows an example of an integrated electric circuit having staggered rows of contact pads.

FIG. **8** is an oblique bottom view of a probe suitable for use in another embodiment of the invention.

FIG. **9** is an oblique bottom view of a probe array suitable for use in yet another embodiment of the invention.

FIG. **10** is an oblique top view of the probe array of the embodiment of FIG. **9**.

DETAILED DESCRIPTION

FIGS. **1-4** show various views of a probe array according to an embodiment of the invention. More specifically, FIG. **1** shows an oblique top view, FIG. **2** shows an oblique bottom view, FIG. **3** shows a top view, and FIG. **4** shows a side view. In these views, a probe array **100** includes several vertical probes, some of which ate labeled as **302**, **304**, and **306**. Each probe in the array has a base section (e.g., base section **102**) and a tip section

(e.g., tip section **104**), where the base section and the tip section are at opposite ends of the probe. Each probe tip section has a tip contact surface (e.g., contact section **106**) for making electrical contact to a device under test. The direction of probe base section motion as contact is made is vertical on FIG. **4** (i.e., parallel to the dotted lines of FIG. **4**).

The tip sections of the probes are disposed such that the corresponding tip contact surfaces are disposed along a straight contact line (**108** on FIG. **2**). The base sections of the probes are disposed in a two-dimensional base array having at least two rows parallel to the contact line. In the example of FIGS. **1-4**, there are three rows in the base array. A thickness of the base sections along the rows is substantially larger than a center to center spacing of adjacent tip contact surfaces along the contact line (e.g., as shown on FIGS. **1-4**). In this manner, closely spaced contact pads can be probed with a vertical probe array without requiring the entire length of the probes to have a thickness smaller than the contact pad spacing. Only the tip sections of the probes need to have such a small thickness. The base sections can be made thicker, which is advantageous for preventing lateral deformation (i.e., deformation in the direction of contact line **108**) of probes when contact is made to the device under test. This arrangement of probes can be regarded as proving a space transformation function from a single row of contact pads to multiple rows in the base array.

Although it is not required, it is usually preferred for probes in each row of the base array to have the same shape. In this example, probes in the same row as probe **302** have the same shape as probe **302**, probes in the same row as probe **304** have the same shape as probe **304**, and probes in the same row as probe **306** have the same shape as probe **306**. Since the distance between the rows of the base array and the contact line varies from row to row, probe shapes differ from row to row. Thus any two probes belonging to different rows of the base array will have different shapes.

To define how the probe shapes differ from row to row, it is helpful to define a tip to base offset for each probe. For example, FIG. **4** shows tip to base offsets **402**, **404**, and **406** for probes **302**, **304**, and **306** respectively. Adjacent rows have tip to base offsets which differ by the spacing between the adjacent rows, thereby providing alignment of the tips to a single contact line. For vertical knee probes, as in the example of FIGS. **1-4**, it is important to note that the base to tip offset for a particular probe can be positive, zero, or negative. Without loss of generality, the tip to base offsets shown on FIG. **4** are taken to be positive. Thus a positive tip to base offset relates to a knee probe where the base axis is between the tip and the knee. Another way to describe a positive offset is that the knee “comes back in” further than it “goes out” as one moves from base to tip. Thus a negative tip to base offset relates to a situation where the knee “goes out” more than it “comes back in” as one moves from base to tip. The resulting probe configuration has the tip between the base axis and the knee. Finally, a tip offset of zero relates to the case where the tip and base axis are aligned.

Although the example of FIGS. **1-4** shows all probes having a positive tip to base offset, the invention can be practiced with probes have positive, negative and/or zero offset, provided the offsets vary from row to row as described above.

To provide uniformity of probing, it is preferred for each of the vertical probes in the probe array to provide substantially the same scrub motion between tip contact surface and the contact pad of the device under test as contact is made. The tip to base offset is an important parameter that can significantly affect the scrub motion of the probe, as described in greater detail in U.S. Pat. No. 7,148,709 and in U.S. patent application Ser. No. 11/450,977, both by the present inventor. However, vertical probe designs have other degrees of freedom for controlling the scrub motion in addition to the tip to base offset, so these other parameters can vary from row to row in such a way as to compensate for the effect of the different offsets for each row.

Embodiments of the invention are particularly suitable for probing closely spaced contact pads, since conventional vertical probing of such contact pads can encounter difficulties as described above. For example, in practicing the invention, the center to center spacing of the tip contact surfaces along the contact line can be from about 50 μm to about 100 μm. The center to center spacing of the base sections along the rows of the base array is preferably between about 150 μm and about 200 μm.

It is preferred for each of the probes to deform primarily in a single plane, with minimal out-of plane deformation during contact. This probe plane (or deformation plane) is perpendicular to contact line **108** (i.e., it is the plane of FIG. **4**). This property, which is enabled by the increased thickness of the base sections compared to the tip sections, is highly desirable for avoiding probe-to-probe electrical shorts during device test.

Although the preceding description relates to an example where a probe array according to an embodiment of the invention is configured to make contact to a single row of contact pads, the invention is also applicable to making contact to two or more rows of contact pads. For example, contact can be made to two rows of contact pads **502** and **504**, as shown on FIG. **5**. More specifically, FIG. **6** shows a top view of an embodiment of the invention where two probe arrays (**602** and **604**) are configured to make contact to two rows of contact pads (as on FIG. **5**). Each row of contact pads has its corresponding array of probes, and each of these arrays provides a one row to multiple row space transformation as described above.

In making contact to multiple rows of contact pads according to embodiments of the invention, the rows of contact pads can have any arrangement relative to each other. However, devices under test often provide rows of contact pads that are parallel to each other, have the same contact pad spacing and are offset from each other by a tip row offset that is about half the contact pad spacing (e.g., as shown on FIG. **5**). For example, contact pads having a spacing of about 50 μm to about 100 μm can have an offset of about 25 μm to about 50 μm. Thus a preferred embodiment of the invention provides corresponding probe arrays (e.g., as shown on FIG. **6**).

FIG. **7** shows an example of an integrated electric circuit having staggered rows of contact pads. Circuit **702** includes 4 sets of contact pads, **706**, **708**, **710**, and **712**, each of which can be probed with a corresponding probe array as described above in connection with FIG. **6**. In corner overlap regions, such as region **704**, probes corresponding to one set of contact pads (e.g., set **706**) may interfere with probes from another set of contact pads (e.g., set **712**). If such interference is of concern, the affected contact pads can be probed by conventional methods that avoid probe interference, or the contact pads can be arranged to eliminate the interference. For example, probes for contact pad set **710** extend into corner overlap region **714**, but contact pad set **708** is configured such that none of its corresponding probes need to extend into region **714**. In this manner, interference between probes can be avoided in practicing the invention.

The preceding description is by way of example as opposed to limitation, so the invention can also be practiced according to many variations of the preceding embodiments. For example, it is not critical exactly how the probe thickness decreases in the transition from base section to tip section. A single abrupt transition as shown on FIGS. **1-4** is one possibility. FIG. **8** shows a probe having a base section **802**, a tip section **804** and a base to tip transition region **808** to reduce stress concentration at the transitions and to increase overall probe stiffness. Such a “stepped taper” is compatible with layer by layer probe fabrication, which is preferred for fabricating probes according to embodiments of the invention. The example of FIG. **8** shows a stepped taper having two transitions. Any number of transitions in a stepped taper can be employed in practicing the invention.

In practicing the invention, details of the probe tip shape are also not critical. However, a "skate" (e.g., **806** on FIG. **8**) on the tip contact surface having a narrower width that the probe tip is a preferred configuration compared to the full-width contact surface **106** of FIG. **2**.

Details of the overall probe shape are also not critical in practicing the invention. FIGS. **9** and **10** show two views of a probe array according to an embodiment of the invention where the probes have straight vertical sections **902**. In contrast, the example of FIGS. **1-4** shows probes having curved vertical sections. The example of FIGS. **9** and **10** also shows making contact to two rows of contact pads (i.e., along lines **904** and **906**), as in the example of FIG. **6**. However, the example of FIG. **6** shows the probe arrays arranged on opposite sides of the contact lines, while the example of FIGS. **9** and **10** shows the probe arrays arranged on the same side of the contact lines. This possibility provides another solution to the problem of possible probe interference as described in connection with FIG. **7**, since sets of contact pads **706**, **708**, **710**, and **712** can all be probed from outside the square they form.

Suitable materials for probes and probe tips to be included in probe arrays of the invention are well known in the art, and any such materials can be employed in practicing the invention. Suitable tip materials are electrically conductive and wear-resistant, and include Rh and Cr. Suitable probe fabrication, manufacturing, assembly and mounting methods for making probe arrays according to embodiments of the invention are also well known in the art.

What is claimed is:

1. A probe array comprising:
at least two rows of vertical probes;
said adjacent tip sections of the probes aligned along an axis comprising a first center to center spacing;
said adjacent base sections of the probes in each row comprising a second center to center spacing;
said second center to center spacing greater than said first center to center spacing; and
wherein said rows of probes are disposed on a same side of said axis.

2. The apparatus of claim **1** wherein said base sections comprise a thickness substantially larger than said center to center spacing of said adjacent tip sections.

3. The apparatus of claim **1** wherein said probe array contacts a contact surface and said rows of said probe array are parallel to a plurality of contact pads on the contact surface, wherein the contact pads are contacted by said tip sections.

4. The apparatus of claim **1** wherein said vertical probes comprise straight sections.

5. The apparatus of claim **1** wherein said vertical probes comprise curved sections.

6. The apparatus of claim **1** wherein said probes in each said row of said base array have a same shape.

7. The apparatus of claim **1** wherein said rows of probes have different shapes.

8. The apparatus of claim **1** wherein said probes provide a substantially same scrub motion on a contact surface.

9. The apparatus of claim **1** wherein said base sections are thicker than said tip sections.

10. The apparatus of claim **1** wherein said probes are vertical knee probes.

11. The apparatus of claim **1** wherein at least one probe has a positive base to tip offset.

12. The apparatus of claim **1** wherein at least one probe has a negative base to tip offset.

13. The apparatus of claim **1** wherein at least one probe has a zero base to tip offset.

14. The apparatus of claim **1** wherein a distance between said rows of said probe array vary from row to row.

15. The apparatus of claim **1** wherein said first center to center spacing of said tip sections is from about 50 μm to about 100 μm.

16. The apparatus of claim **1** wherein said second center to center spacing of said base sections is between about 150 μm to about 200 μm.

17. The apparatus of claim **1** wherein said probes deform primarily in a single plane.

18. The apparatus of claim **1** wherein said probes deform primarily in a single plane, said plane perpendicular to said axis.

19. The apparatus of claim **1** wherein said probes have minimal out-of-plane deformation during contact.

20. The apparatus of claim **1** wherein said probes contact a single row of contact pads on a contact surface.

21. The apparatus of claim **1** comprising multiple probe arrays for contacting multiple rows of contact pads on a contact surface.

22. The apparatus of claim **1** wherein said rows of said base array are staggered.

23. The apparatus of claim **1** wherein said probes contact a plurality of contact pads disposed in a corner of an integrated electric circuit.

24. The apparatus of claim **1** wherein said probes comprise at least one base to tip transition region.

25. The apparatus of claim **1** wherein each said tip section comprises a skate.

26. The apparatus of claim **25** wherein said skate comprises a narrower width than said tip section.

27. The apparatus of claim **1** wherein said tip sections comprise an electrically conductive and wear-resistant material.

28. The apparatus of claim **27** wherein said tip section comprises Rh.

29. The apparatus of claim **27** wherein said tip section comprises Cr.

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